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Effect of Plant Growth Regulators on Fruit Set and Quality of Kinnow Mandarin (*Citrus reticulata* Blanco)

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ABSTRACT

A field experiment was carried out to study the effect of different plant growth regulators on fruit Set and growth of kinnow mandarin (*Citrus reticulata* Blanco) at horticultural orchard of School of Agriculture, Lovely Professional University, Phagwara during 2021- 2022. During the study three different PGRs at different concentrations were applied viz., GA_3 (5, 10, 15 ppm), NAA (5, 10, 15 ppm) and 2, 4-D (10, 15, 20 ppm). The results revealed that maximum fruit set was observed with GA_3 (10 ppm) and fruit retention 2, 4- D (15 ppm). Among physical and quality parameters viz., Fruit length, Fruit diameter, Fruit weight, Peel thickness, TSS, Titrable acidity and Ascorbic acid application of NAA (10 ppm) found to be most superior. Whereas, GA_3 (10 ppm) resulted in minimum number of seeds per fruit.

Keywords Kinnow, PGR, Fruit set, Fruit quality, *Citrus reticulata.*

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INTRODUCTION

Citrus fruits have special place among all the other fruits grown in the horticulture because of its high nutritive value and decent productivity. Among all the citrus cultivar kinnow is one of the most important fruit crops. Kinnow mandarin (*Citrus reticulata* Blanco) is an important hybrid of 'King' (*Citrus nobilis*) x 'Willow leaf' (*Citrus deliciosa*). Kinnow covers almost 40 % (5101 thousand MT) of total citrus production (12546 thousand MT) in India (NHB 2018). Kinnow is grown extensively in Punjab, Madhya Pradesh, Haryana, and Rajasthan in India. In Punjab Kinnow accounts for nearly 63.3 % of fruit production (1908.85 thousand MT) with an average production of 1208.42 thousand MT (NHB 2018).

Kinnow is cultivated for its high consumer appeal, wider adaptability, heavy bearing, more economic return, appealing golden-orange fruit colour, and superior juice quality with a distinctive flavour. Kinnow is also known for antioxidants, flavonoids, vitamins, minerals, and especially limonin glucosides, which have anti-cancer qualities, and is also low in saturated fat and cholesterol. Its pulp is used in jam, squash, juice, sauce, and syrup, and its outer skin is used in cosmetics and essence. Further, it is also the primary source of citric acid and peel oil, both of which have a high international market value.

Despite being profitable and nutritive crop fruit drop and higher number of seeds per fruits is one of the major problem in kinnow. Preharvest fruit drop is a major cause of low yield, and it is caused by malnutrition, water stress, excessive insect pest attack,

and, most importantly, hormonal imbalance (Mir and Itoo 2017). Fruit drop occurs when the concentration of auxins decreases and the concentration of abscisic acid (ABA) increases, as endogenous hormones and their balance modulate nutrient mobilization to developing organs (Marinho *et al.*2005). Further, the high number of seeds per fruit of Kinnow is the critical obstacle that restricts its utility for various value-added products besides raw consumption (Khalil *et al.* 2011). The exogenous application of Plant Growth Regulators can regulate these drops and improve fruit quality. Therefore, keeping in view the above mention points the present study has been planned.

MATERIALS AND METHODS

The experiment was carried out in an already established six years old kinnow mandarin plantation in the horticultural orchard of School of Agriculture, Lovely Professional University, Phagwara, Punjab during the year 2021-2022. The experiment was carried out in Randomized Block Design (RBD) with ten treatments and three replications viz., GA_3 (5 ppm), GA_3 (10 ppm), GA_3 (5 ppm), NAA (5 ppm) NAA (10 ppm), NAA (15 ppm), 2, 4-D (10 ppm), 2, 4-D (15 ppm), 2,4-D (20 ppm) and Control (Water spray). The selected kinnow trees were sprayed with PGRs at three different stages viz., Pre bloom, Full bloom and Post bloom.

Observations on Initial fruit set and fruit retention were recorded throughout the fruiting period. Fruit length, diameter, peel thickness, seed length and seed breadth of randomly selected fruits were measured using Digital Vernier Caliper (Mitutoyo) and the average value was expressed in millimeters (mm). Fruit weight was measured using digital electronic balance (Wensar) and expressed in grams (g). To determine the number of aborted and healthy seeds, the seeds were extracted and categorized in two different groups i.e., aborted and healthy seeds. Then the average number of aborted and healthy seeds per

Table 1. Effect of plant growth regulators on initial fruit set (%) and fruit retention (%) of Kinnow mandarin.

Treatment	Initial fruit set (%)				Fruit retention (%)			
	Pre bloom	Full bloom	Post bloom	Mean	Pre bloom	Full bloom	Post bloom	Mean
GA_3 (5 ppm)	48.87 (44.35)	64.60 (53.48)	50.88 (45.50)	54.78 (47.74)	16.34 (23.84)	15.96 (23.54)	19.36 (26.10)	17.22 (24.51)
GA_3 (10 ppm)	55.03 (47.88)	71.02 (57.43)	54.94 (47.83)	60.33 (50.96)	17.84 (24.98)	17.76 (24.92)	18.83 (25.71)	18.14 (25.20)
GA_3 (15 ppm)	53.16 (46.81)	63.46 (52.80)	52.22 (46.27)	56.28 (48.60)	16.71 (24.12)	15.55 (23.22)	16.99 (24.34)	16.42 (23.90)
NAA (5 ppm)	50.24 (45.13)	62.77 (52.39)	51.71 (45.98)	54.91 (47.81)	18.45 (25.43)	17.15 (24.46)	16.44 (23.92)	17.35 (24.61)
NAA (10 ppm)	54.04 (47.31)	69.21 (56.29)	53.83 (47.19)	59.03 (50.20)	17.72 (24.89)	17.46 (24.69)	18.07 (25.15)	17.75 (24.91)
NAA (15 ppm)	49.97 (44.98)	64.27 (53.29)	50.67 (45.38)	54.97 (47.85)	21.29 (27.47)	15.93 (23.52)	18.37 (25.37)	18.53 (25.49)
2,4 -D (10 ppm)	50.28 (45.16)	60.07 (50.80)	52.63 (46.50)	54.33 (47.48)	16.91 (24.28)	17.26 (24.54)	18.90 (25.76)	17.69 (24.87)
2,4 -D (15 ppm)	52.88 (46.65)	66.93 (54.89)	52.96 (46.69)	57.59 (49.36)	18.73 (25.64)	17.78 (24.93)	21.77 (27.81)	19.43 (26.15)
2,4 -D (20 ppm)	51.77 (46.01)	62.38 (52.16)	51.77 (46.01)	55.31 (48.04)	17.70 (24.87)	16.20 (23.73)	18.20 (25.25)	17.37 (24.63)
Control (Water spray)	47.22 (43.40)	48.33 (44.04)	48.13 (43.92)	47.89 (43.79)	16.35 (23.85)	16.57 (24.02)	16.03 (23.60)	16.32 (23.82)
Mean	51.34 (45.76)	63.30 (52.71)	51.97 (46.12)		17.80 (24.95)	16.76 (24.16)	18.29 (25.31)	
CD at 5%	PGR Stage PGR × Stage		2.67 4.62 NS		PGR Stage PGR× Stage		0.84 1.46 NS	

Table 2. Effect of plant growth regulators on fruit length (mm), fruit diameter (mm) and fruit length diameter ratio of Kinnow mandarin.

Treatment	Fruit length (mm)				Fruit diameter (mm)				Fruit length diameter ratio			
	Pre bloom	Full bloom	Post bloom	Mean	Pre bloom	Full bloom	Post bloom	Mean	Pre bloom	Full bloom	Post bloom	Mean
GA_3 (5 ppm)	51.34	54.62	56.21	54.06	56.23	54.62	57.11	55.99	0.91	0.91	0.98	0.93
GA_3 (10 ppm)	52.17	53.98	56.17	54.11	55.15	53.98	57.13	55.42	0.94	0.89	0.98	0.94
GA_3 (15 ppm)	52.69	54.03	53.96	53.56	54.24	54.03	58.61	55.63	0.97	0.95	0.92	0.95
NAA (5 ppm)	54.26	56.24	57.14	55.88	59.21	56.24	61.22	58.89	0.91	0.94	0.93	0.93
NAA (10 ppm)	59.27	59.45	61.44	60.05	62.45	59.45	66.25	62.72	0.94	0.93	0.92	0.93
NAA (15 ppm)	55.26	58.17	56.95	56.79	59.19	58.17	63.57	60.31	0.93	0.96	0.89	0.93
2,4 -D (10 ppm)	53.67	54.99	56.19	54.95	56.19	54.99	61.49	57.56	0.95	0.92	0.91	0.93
2,4 -D (15 ppm)	57.11	58.21	59.35	58.22	61.55	58.21	63.75	61.17	0.92	0.93	0.93	0.93
2,4 -D (20 ppm)	54.47	57.44	57.21	56.37	58.94	57.44	62.84	59.74	0.92	0.95	0.91	0.93
Control (Water spray)	49.5	48.93	50.61	49.68	51.34	48.93	55.26	51.84	0.96	0.90	0.91	0.92
Mean	53.97	55.60	56.52		57.44	55.60	60.72		0.93	0.92	0.92	
CD at 5%	PGR	2.64			PGR	2.83			PGR	NS		
	Stage	2.31			Stage	2.09			Stage	NS		
	PGR x Stage	NS			PGR x Stage	NS			PGR x Stage	NS		

fruit were counted respectively. TSS of fruits were measured using hand refractometer (ERMA made). Acidity and Ascorbic acid were estimated as per the method suggested by AOAC (2000).

RESULTS AND DISCUSSION

The foliar application of plant growth regulators significantly improved fruit set and fruit retention (Table1). Foliar application of GA_3 at 10 ppm resulted in highest initial fruit set followed by NAA (10 ppm) (Table 1). The application of PGRs kinnow mandarin at various flowering stages also resulted in significant differences in the initial fruit set percentage. The application of GA_3 (10 ppm) during full bloom stage resulted in higher fruit set. The increase in fruit set and percent fruit set could be attributed to GA_3's increased availability of nutrients from leaves, or it could be due to varietal genetic ability to set a high or low percentage of fruits (Fahad and Rab 2014). This findings on fruit set were consistent with those of Huang and Huang (2005), who discovered that a foliar application of GA_3 at 50 mg/l sprayed during the citrus flower fall stage resulted in good fruitlet protection and improved fruit set. Similar results were also obtained by Nawaz *et al.* (2011) in Kinnow and Bhatt *et al.* (2016) in Lemon. The maximum fruit retention was observed under treatment with 2, 4-D (15 ppm) which was followed by NAA (15 ppm) (Table 1). Application of 2, 4-D increases auxin levels, which control the formation of the abscission layer between the fruit pedicel and stem and it leads to decrease in fruit drop (Kavinprashanth *et al.* 2021). Similar findings on fruit retention were reported by Sihag *et al.* (2019) in Kinnow and Choudhary *et al.* (2013) in Nagpur mandarin.

The data revealed that application of different PGRs resulted in significant differences in fruit size. The maximum fruit length and diameter was recorded in treatment with NAA (10 ppm) followed by 2, 4-D (15 ppm) (Table 2). Whereas, the treatment with GA_3 (15 ppm) resulted in maximum fruit length diameter ratio. Higher amounts of auxins in the plant and fruit were reported to enhance the mobilization of food and nutrient (Kumar 2021). The study of Bharti (2020) revealed that application of NAA significantly improved fruit length as compared to control.

Similarly, fruits treated with NAA at 10 ppm resulted in maximum fruit weight (169.51 g) followed by 2, 4-D (15 ppm) (Table 3). Whereas, the maximum peel thickness was recorded in treatment with GA_3 (15 ppm) (Table 3). The improvement in physical parameters of fruit with exogenous application of PGRs may be attributed to accelerated fruit growth and eventually, increased fruit size by increasing

Table 3. Effect of plant growth regulators on fruit weight (g) and peel thickness (mm) of Kinnow mandarin.

Treatment	Fruit weight (g)				Peel thickness (mm)			
	Pre bloom	Full bloom	Post bloom	Mean	Pre bloom	Full bloom	Post bloom	Mean
GA_3 (5 ppm)	158.49	152.84	150.36	153.90	3.53	3.51	3.56	3.53
GA_3 (10 ppm)	156.91	157.67	147.23	153.94	3.54	3.50	3.60	3.55
GA_3 (15 ppm)	155.21	151.89	145.21	150.77	3.63	3.63	3.69	3.65
NAA (5 ppm)	157.41	158.36	162.67	159.48	3.52	3.46	3.56	3.51
NAA (10 ppm)	166.67	166.91	174.95	169.51	3.46	3.51	3.54	3.50
NAA (15 ppm)	160.24	160.29	170.07	163.53	3.48	3.49	3.49	3.49
2,4 -D (10 ppm)	152.89	151.21	160.84	154.98	3.54	3.48	3.52	3.51
2,4 -D (15 ppm)	160.49	161.47	172.49	164.82	3.52	3.47	3.51	3.50
2,4 -D (20 ppm)	158.46	159.11	169.64	162.40	3.46	3.44	3.53	3.48
Control (Water spray)	138.35	145.27	143.41	142.34	3.43	3.41	3.45	3.43
Mean	156.51	156.50	159.68		3.51	3.49	3.54	
CD at 5%	PGR		7.53	PGR		0.02		
	Stage		4.73	Stage		0.01		
	PGR x Stage		NS	PGR x Stage		NS		

cell enlargement (Bharti 2020). Similar findings were reported by Shireen *et al.* (2018) in kinnow and Kumar (2021) in sweet orange and Devi *et al.* (2015) in kinnow.

Table 4. Effect of plant growth regulators on seed length (mm), seed breadth (mm), number of healthy and aborted seeds per fruit of Kinnow mandarin.

Treatment	Seed length (mm)				Seed breadth (mm)				Number of healthy and aborted seeds per fruit			
	Pre bloom	Full bloom	Post bloom	Mean	Pre bloom	Full bloom	Post bloom	Mean	Pre bloom	Full bloom	Post bloom	Mean
GA_3 (5 ppm)	10.09	10.72	10.20	10.34	5.17	5.11	4.60	4.96	17.03 (2.99)	16.05 (3.11)	13.65 (3.39)	15.58 (3.16)
GA_3 (10 ppm)	9.29	9.42	9.41	9.37	4.88	4.58	4.57	4.68	13.29 (2.89)	11.39 (3.89)	10.76 (3.91)	11.81 (3.56)
GA_3 (15 ppm)	10.62	9.83	9.79	10.08	5.03	4.77	4.61	4.80	14.14 (2.96)	14.22 (3.23)	12.71 (3.15)	13.69 (3.11)
NAA (5 ppm)	11.68	10.88	10.91	11.16	5.36	5.10	5.29	5.25	22.44 (1.97)	20.66 (2.49)	21.04 (2.47)	21.38 (2.31)
NAA (10 ppm)	11.29	11.01	10.60	10.97	5.15	5.86	4.77	5.26	20.77 (2.40)	19.66 (2.70)	16.97 (3.38)	19.13 (2.83)
NAA (15 ppm)	11.38	10.81	10.82	11.00	5.29	5.03	5.10	5.14	21.80 (2.32)	20.45 (2.39)	18.47 (2.49)	20.24 (2.40)
2,4 -D (10 ppm)	11.53	11.79	11.02	11.45	5.38	5.10	5.29	5.26	22.57 (1.89)	21.78 (1.95)	20.16 (2.32)	21.50 (2.05)
2,4 -D (15 ppm)	11.44	10.85	10.78	11.02	5.25	5.16	4.23	4.88	20.99 (2.27)	20.34 (2.55)	19.19 (2.78)	20.17 (2.53)
2,4 -D (20 ppm)	11.34	11.24	10.72	11.10	5.29	5.16	5.39	5.28	21.10 (2.45)	21.10 (2.50)	20.20 (2.53)	20.80 (2.49)
Control (Water spray)	12.21	11.98	11.91	12.03	5.54	5.51	5.60	5.55	24.23 (1.90)	24.44 (1.91)	23.40 (1.96)	24.02 (1.92)
Mean	11.08	10.85	10.61		5.23	5.13	4.94		19.83 (2.40)	19.00 (2.67)	17.65 (2.83)	
CD at 5%	PGR		0.52		PGR		0.12		PGR		0.92 (0.12)	
	Stage		0.90		Stage		0.21		Stage		0.89(0.07)	
	PGR x Stage		NS		PGR x Stage		NS		PGR x Stage		NS (0.22)	

Figures in parenthesis are number of aborted seeds per fruits.

Table 5. Effect of plant growth regulators on TSS (°Brix) titrable acidity (%) and ascorbic acid (mg/100 of juice) of Kinnow mandarin.

Treatments	TSS (°Brix)				Titrable acidity				Ascorbic acid			
	Pre bloom	Full bloom	Post bloom	Mean	Pre bloom	Full bloom	Post bloom	Mean	Pre bloom	Full bloom	Post bloom	Mean
GA_3 (5 ppm)	9.16	8.23	9.08	8.82	0.93	0.95	0.96	0.95	26.51	26.16	26.57	26.41
GA_3 (10 ppm)	9.28	9.14	8.91	9.11	0.99	1.01	1.04	1.01	25.98	25.23	24.97	25.39
GA_3 (15 ppm)	8.84	8.34	8.75	8.64	0.97	0.99	1.01	0.99	26.23	26.63	25.42	26.09
NAA (5 ppm)	9.23	9.38	9.46	9.36	0.92	0.92	0.97	0.94	28.52	29.12	30.23	29.29
NAA (10 ppm)	9.84	9.95	10.03	9.94	0.89	0.88	0.90	0.89	30.88	32.39	33.87	32.38
NAA (15 ppm)	9.34	9.41	9.76	9.50	0.87	0.90	0.87	0.88	29.46	30.13	30.63	30.07
2,4 -D (10 ppm)	9.25	9.28	9.42	9.32	0.90	0.87	0.89	0.89	28.47	29.41	29.97	29.28
2,4 -D (15 ppm)	9.47	9.43	9.56	9.49	0.88	0.89	0.91	0.89	29.16	30.43	31.39	30.33
2,4 -D (20 ppm)	9.27	9.25	9.39	9.30	0.85	0.86	0.88	0.86	28.85	29.40	30.61	29.62
Control (Water spray)	8.51	8.60	8.90	8.67	0.94	0.94	0.95	0.94	25.15	25.97	25.34	25.49
Mean	9.21	9.10	9.32		0.91	0.92	0.93		27.92	28.48	28.90	
	PGR		0.44		PGR		0.04		PGR		1.36	
CD at 5%	Stage		0.26		Stage		0.07		Stage		1.06	
	PGR x Stage		NS		PGR x Stage		NS		PGR x Stage		NS	

The application of plant growth regulators significantly decreased the number of seeds per fruit, length and breadth of the seeds (Table 4).The minimum length and breadth of seeds were observed in treatment with GA_3 (10 ppm) closely followed by GA_3 (15 ppm). Similarly, the minimum number of healthy and maximum number of aborted seeds per fruit were recorded in treatment with GA_3 (10 ppm). In terms of application phases, the post bloom stage was shown to be significantly superior as compared to the pre and full bloom stages. The decrease in the number of seeds/fruit could be due to GA_3's stimulatory influence on parthenocarpic fruit development (Zhang 2003). Our findings were in accordance with Nawaz *et al.* (2011) in Kinnow, Jagtap *et al.* (2013) in Acid lime and Bhatt *et al.* (2016) in Lemon.

The quality parameters of fruits were significantly influenced by the application of PGRs (Table 5). The fruits harvested from trees sprayed with NAA (10 ppm) had the highest TSS and ascorbic acid content. Whereas, the minimum acidity percentage was recorded in treatment with 2, 4-D (20 ppm) closely followed by NAA (15 ppm). The beneficial effect of auxins may be due to their influence on physiological processes, particularly respiration and photosynthesis, which may have resulted in the formation of dry matter, minerals, and carbohydrates (Jain *et al.* 2014). The results are in accordance with the study of Ghosh *et al.* (2012) in sweet orange, Kumar (2021) in sweet orange and Shireen *et al.* (2018) in Kinnow.

Overall, it can be concluded that application of PGRs revealed prominent results on fruit set and quality in Kinnow mandarin. The treatment with NAA (10 ppm) showed superior results in terms of physical and biochemical parameters. Fruits treated with GA_3 (10 ppm) had lowest seeds per fruit.

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